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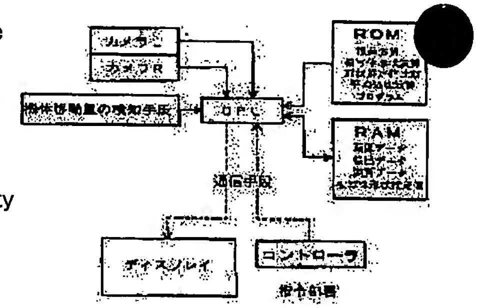
(54) HIGH PRECISION STEREO VISION USING CONTINUOUS FRAME IMAGE

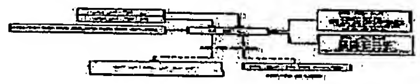
(57)Abstract:



PROBLEM TO BE SOLVED: To provide a stereo camera system capable of solving the problem in the stereo camera system, ensuring corresponding point search between two images to thereby make deduction of a parallax value accurate, thereby increasing certainty of object shape recognition, and heightening its reproduction accuracy.

SOLUTION: In this high precision stereo vision using a continuous

frame image, plural pairs of stereo images from different viewpoints of a non- deformable object, and the corresponding point search having high correlation between each pair of images is executed to detect the parallax, and the object shape is operated from the parallax value, and the corresponding point search is executed similarly between each pair, and the object shape is operated, and data are accumulated, and overall operation of accumulated information is executed, to thereby ensure the object shape estimation value.



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parallax value, and a means which carries out the comprehensive operation of the photographic subject configuration information based on two or more sets of stereo images which differ in a viewing angle, and makes photographic subject configuration estimate a clear thing.

[Translation done.]

CLAIMS

[Claim(s)]
[Claim 1] The step which acquires two or more sets of stereo images from the view when the photographic subjects not deforming differ, The step which performs high corresponding-points retrieval of the correlation between the images of each class, and detects parallax, The step which calculates a photographic subject configuration from this parallax value, and the step which performs corresponding-points retrieval similarly in each class, calculates a photographic subject configuration, and stores data, The high precision stereo vision using the continuation frame image which consists of a step which carries out the comprehensive operation of these two or more sets of are recording information, and makes photographic subject configuration estimate a clear thing.
[Claim 2] The comprehensive operation approach of are recording information is a high precision stereo vision using the continuation frame image according to claim 1 which is average processing or weighted-mean processing of radical rectangle-like estimate at two or more sets of stereo images.
[Claim 3] The photographic subject configuration estimate with the low correlation with the photographic subject configuration estimate of other groups is a high precision stereo vision using the continuation frame image according to claim 1 or 2 excepted from the are recording information adopted in a comprehensive operation.
[Claim 4] Two cameras which took predetermined spacing on the body which can move and were installed, A storage means to memorize the image photoed with the camera of these two bases, and a means to perform corresponding-points retrieval from the this memorized image of two sheets, and to deduce parallax, The high precision stereo vision system using the continuation frame image which consists of a means which carries out the presumed operation of the photographic subject configuration from said

* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] the technique of recognizing geographical feature with a sufficient precision from two or more image information which photoed this invention with the stereoscopic camera which moves — being related — especially — the moon's surface — it is related with the technique of the stereoscopic camera suitable for the terrain sensing in the case of soft landing.
[0002]
[Description of the Prior Art] Based on the image of two sheets photoed with two cameras by which predetermined distance detached building ****** was carried out , what the technique of a stereo photograph of recognize the three dimensions configuration of a photographic subject looks at the image of two sheets separately by the eye on either side , and carries out stereoscopic vision by vision , and the technique of find the point information which corresponds out of [of two sheets] an image , and search for the depth coordinate of the point by the operation from the parallax are known . by the way, our country — setting — the near moon's surface uninhabited in the future — a plan to soft-land a probe at the moon's surface — it is — the moon's surface — in order to ensure soft landing, the location of a crater, rock, etc. which are distributed over the moon's surface is recognized, and the technique which guides and controls a probe that it should be avoided becomes important. For that purpose, recognition of the geographical feature using field-of-view information is indispensable, and the three-dimensions shape-recognition technique using this stereoscopic camera and the method of the above-mentioned latter attract attention.
[0003] Here, the principle of the geographical feature detection by the stereoscopic camera is explained. In the external world recognition by stereo ** using two cameras, the parallax of the point on an image is searched for

from the corresponding points of the camera image of right and left by one photography, and the coordinate of the point is searched for based on a degree type.
x=b(xL+xR) /2dy=b(yL+yR)/— as f is parallax and shows a focal distance and b to drawing 3 for the base-line distance between cameras, and d 2 dz=bf/d here (xL, yL), (xR, yR) are the coordinates of the corresponding points in a right-and-left camera screen. Thus, if parallax is searched for by corresponding-points retrieval of each point on a camera image on either side and the distance to the point of the external world of from now on corresponding is found, front geographical feature can be found.
[0004] Although there is some technique in corresponding-points retrieval of the camera image of the above right and left, area-based-matching is used for the typical thing. This evaluates the difference of the image for every pixel like for example, a degree type in the window set up on the camera image on either side as shown in drawing 4 .
[Equation 1]

$$J_1 = \sum_{i,j} |p_{ijL} - p_{ijR}| \quad : \text{絶対和}$$

$$J_2 = \sum_{i,j} (p_{ijL} - p_{ijR})^2 \quad : \text{誤差二乗和}$$

The performance index about the difference of the image in the window of such right and left is compared on a straight line, the points from which it becomes min are made into corresponding points, and distance information is searched for from the parallax. However, when the similarity of the pattern in the location where it differs on the same image in that case is strong, or when there is an image noise, corresponding-points retrieval goes wrong, a different point is made to correspond, a parallax value is taken and calculated, and it happens to mistake presumption of geographical feature greatly. Moreover, as mentioned above, by the stereo image processing only using one frame of a camera, even if geographical feature detection of the whole screen can be impossible for it even if partial geographical feature detection is possible, or it can detect it, it may be accompanied by gross errors. Thus, this stereoscopic camera method is the difficulty of the corresponding-points retrieval between the images of two sheets etc., and a problem is in the certainty and implementation precision of geographical feature recognition.
[0005]
[Problem(s) to be Solved by the Invention] It is to offer a stereoscopic camera method with the high reproducibility while the technical problem of this invention solves the trouble in the above stereoscopic camera methods, makes deduction of the value of parallax exact by making corresponding-points retrieval between the images of two sheets into a clear

time is [Equation 2] by those averages.

$$\underline{Z}_{ij}^{M}=\frac{1}{M}\sum_{k=1}^{M}\underline{Z}_{ijk}$$

Then, it is good. Supposing distribution of the presumed error in each frame is given by sigmaij2, it is the presumed error variance of ZijM. sigmaij2 /M It turns out that it becomes and presumed error variance decreases to 1/M by processing of M frames. The information that dependability with few errors is high can be acquired by taking in data from two or more sets of images about the configuration (depth coordinate value) of each part of a photographic subject as mentioned above. In addition, it is [Equation 3] when taking serial processing into consideration.

$$\underline{Z}_{ij}^{M}=\frac{1}{M}\left\{\underline{Z}_{ijM}+(M-1)\underline{Z}_{ij}^{M-1}\right\}$$

Then, saving of a storage region is [that what is necessary is to memorize only the presumed result of 1 time ago] possible.

[0009] (2) Estimate Zijk in the weighted-mean processing frame k The presumed error variance sigmaij2 If it can evaluate, the probability distribution of Zij which assumes the inter-frame independence of estimate and the normality of the presumed distribution of errors will be [Equation 4].

$$p_k(Z_{ij})=\frac{1}{\sqrt{2\pi\sigma_{ijk}^2}}\exp\left\{-\frac{(Z_{ij}-\underline{Z}_{ijk})^2}{2\sigma_{ijk}^2}\right\}$$

The probability when obtaining the image of M frames, since it became is [Equation 5].

$$p(Z_{ij})_M=\left(\prod_k\frac{1}{\sqrt{2\pi\sigma_k^2}}\right)\times\exp\left\{-\sum_k\frac{(Z_{ij}-\underline{Z}_{ijk})^2}{2\sigma_{ijk}^2}\right\}$$

It becomes. The optimum estimate (maximum likelihood estimation) when obtaining the image of M frames, when writing what changed the sign of exponent part to be J is [Equation 6].

$$\frac{\partial J}{\partial Z_{ij}}=\sum_k\frac{(Z_{ij}-\underline{Z}_{ijk})}{\sigma_{ijk}^2}=0$$

It is [Equation 7] more.

$$\underline{Z}_{ij}^{M}=\left(\sum_k\frac{1}{\sigma_{ijk}^2}\right)^{-1}\left(\sum_k\frac{\underline{Z}_{ijk}}{\sigma_{ijk}^2}\right)$$

thing and therefore increases the certainty of a photographic subject shape recognition.

[0006]

[Means for Solving the Problem] The high precision stereo vision using the continuation frame image of this invention Acquire two or more sets of stereo images from the view when the photographic subjects not deforming differ, perform high corresponding-points retrieval of the correlation between the images of each class, and parallax is detected. While having calculated the photographic subject configuration from this parallax value, performing corresponding-points retrieval similarly in each class, calculating the photographic subject configuration and storing data, the comprehensive operation of these two or more sets of are recording information is carried out, and it was made to make photographic subject configuration estimate into the clear thing.

[0007]

[Embodiment of the Invention] the photographic subject configuration of this invention be eternal , when the image which continued from the view when a camera be attach to a mobile at and differ can be acquire , if the configuration information acquired with each frame be accumulate and judge synthetically , the probability to take corresponding points in the corresponding points retrieval between images decrease , and the information for every every place point be also base on the basic thought of become high by dependability . That is, if specification by the part based on the image from a different include angle and a different visual field is performed, about each point, the effect of the random noise on an image will decrease by being equalized. the result — the moon's surface — it is possible to achieve highly precise-ization of geographical feature presumption [**** / extending a detection field] in observation of geographical feature.

[0008] Two or more stereo image information processing photoed continuously shows the technique of raising the increment in the count of observation with the recognition precision of geographical feature. First, although it was about the statistics processing for highly-precise-izing, in this invention, the technique of ** average processing and ** weighted-mean processing was adopted.

(1) It is Zijk about the estimate in the frame image k of the geographical features [in / an average processing-object (photographic subject) front face shall be expressed with a absolute space coordinate (X, Y, Z), and / the lattice point on the 2-dimensional coordinate (Xi, Yj)] (depth coordinate value) Zi and j. It shall express. The estimate of the geographical feature using the frame information to the Mth when the estimate of M pieces was obtained by the stereoscopic camera photography which continued at this

landing target geographical feature of using for the landing point observation in soft landing is eternal and the image of a continuation frame (it is several Hz with a present condition technique) can be acquired with landing descent — it is promising as a method of detecting geographical feature. however, this invention — the moon's surface — it is not restricted to the landing point observation in soft landing, in addition can apply to the external world recognition technique in autonomous mobiles, such as a robot, as it is. Moreover, since it is a thing synthesizing the image from a different view, this invention goes into an objective shadow etc., can acquire the image of the part from a different view also about the field (occlusion) where corresponding points do not exist by the camera image on either side, and enables recognition of the shape of surface type without an omission.

[0012]

[Example 1] The basic block diagram of the example of a system in which this invention can be carried out is shown in drawing 1 , and the flow chart of drawing 2 explains the actuation. First, predetermined spacing is given as equipment and the left-hand side camera L and the right-hand side camera R are directly fixed to an airframe. The photography image of a camera on either side is serially accumulated in the image memory area of each RAM using the camera which these cameras L and R are equipped with image sensors, such as CCD, and outputs digital information. [Step 1] This system is equipped with a computer, and CPU of this computer performs corresponding-points retrieval which carries out the comparison (difference) operation for every pixel of both images, and becomes high [a correlation] most about all pixels, and calculates the boom-hoisting information on geographical feature based on [step 2] and this parallax value in quest of parallax [step 3]. After taking in data about two or more sets of stereo images, performing coordinate transformation based on the movement magnitude of the airframe separately measured by the inertia sensor etc. about the boom-hoisting information which asked by performing the same operation and changing into the boom-hoisting information in a certain standard coordinates, sequential storage are recording is carried out. [Step 4] This computer is equipped with the function which carries out comparison examination of the boom-hoisting information on the geographical feature computed from two or more sets of stereo images again [step 6]. That is, when a difference with the data of others [data / of a certain group / configuration presumption] is large, based on majority rule, the stereo image is judged to be what has taken corresponding-points retrieval, and redoes corresponding-points retrieval. In that case, processing which carries out the comparison with the image data of other groups since the noise can be contained in the image, and makes the data of a bad mutually related part a rejection is performed. That is, the image data of the part where estimate

** — the addition with weight of the presumed error in each frame [like] — then, it is good. Namely, presumed error variance sigmaij2 of each frame By based weighting, information more reliable than mere averaging can be acquired about the configuration (depth coordinate value) of each part of a photographic subject. In addition, the formula deformation to a serial-processing mold is [Equation 8] like the case of previous averaging.

$$\frac{1}{\underline{\sigma}_{UM}^2} = \sum_{k=1}^{M} \frac{1}{\sigma_{Uk}^2}$$

とすれば

$$\frac{1}{\underline{\sigma}_{UM}^2} = \frac{1}{\sigma_{UM}^2} + \frac{1}{\underline{\sigma}_{U(M-1)}^2}$$

$\underline{Z}_U^M$ は上記を使って

$$\underline{Z}_U^M = \underline{\sigma}_{UM}^2 \left(\frac{Z_{UM}}{\sigma_{UM}^2} + \underline{\sigma}_{U(M-1)}^2\, \underline{Z}_U^{M-1} \right)$$

と逐次的に求まる。

An operation can be performed as mentioned above with the count using the presumed result of 1 time ago, then small storage capacity.

[0010] now, the moon's surface — although the image serially photoed with the camera installed on a mobile like a probe is in agreement in a camera coordinate, the camera coordinate at each photography time differs in the physical relationship over a photographic subject. If it is the geographical feature of the photographic subject configuration which should be searched for, for example, the moon's surface, it is required the coordinate on the basis of the moon's surface and to ask as information [in / generally / a absolute space coordinate]. Since the camera coordinate corresponding to each frame is different from two or more sets of frames photoed serially [while the camera is exercising] in order to search for the geographical feature in absolute space, data cannot be synthesized, if coordinate transformation is carried out and it is not made in agreement. then, the moon's surface in which the camera was installed in this invention — an inertia sensor etc. detects the movement magnitude of a mobile like a probe, and it is made to carry out amendment conversion of each camera system of coordinates. Correspondence of two or more sets of frames which took a photograph on the time series target by this, and differed in system of coordinates, respectively is attained.

[0011] this invention — the moon's surface — the moon's surface of a probe — the moon's surface which is equivalent to the external world since the

the body which can move and were installed, A storage means to memorize the image photoed with the camera of these two bases, and a means to perform corresponding-points retrieval from the this memorized image of two sheets, and to deduce parallax, It is what consists of a means to calculate a photographic subject configuration from said parallax value, and a means which carries out the comprehensive operation of the photographic subject configuration based on two or more sets of stereo images which differ in a viewing angle, and makes photographic subject configuration estimate a clear thing. if it has a camera, a computer, and a distance detection means as hard — **** — ****ing — this system — the moon's surface — it can carry in a probe, a robot, etc. and — since it is what does so effectiveness as a high precision stereo vision which was described above by this configuration — the moon's surface — it is greatly promising as a system of the external world recognition in presumption and autonomous migration of the destination form in soft landing.

[Translation done.]

differs greatly is deleted [step 8]. Retrieval of corresponding points is again performed based on clear image data, and parallax is deduced [step 9]. Based on a new parallax value, the configuration estimate of the group is calculated again and overwrite storage is carried out [step 10]. The terrain intelligence which performed average processing or average processing with weight for the data adopted as two or more sets of stereo images being effective, and raised dependability is calculated [step 11]. The configuration optimal-estimation information on the calculated result is memorized, and [step 12] and an activity are ended. in addition, this system — the moon's surface — if it is in a probe, communication link connection is made with the controller of its remote command post like a terrestrial pin center,large, and the display for monitors.

[0013]

[Effect of the Invention] The high precision stereo vision using the continuation frame image of this invention The step which acquires two or more sets of stereo images from the view when the photographic subjects not deforming differ, The step which performs high corresponding-points retrieval of the correlation between the images of each class, and detects parallax, The step which calculates a photographic subject configuration from this parallax value, and the step which performs corresponding-points retrieval similarly, calculates a photographic subject configuration; and stores data between each class, Since it consists of a step which carries out the comprehensive operation of this are recording information, and makes photographic subject configuration estimate a clear thing, misconception of corresponding-points retrieval can be prevented and it becomes what has the high dependability of the parallax value as a stereo image. Moreover, since it is a thing synthesizing the photographic subject configuration estimate based on two or more sets of stereo images, the estimate is reliable and highly precise-ization is measured. As the comprehensive operation approach of are recording information, if average processing of radical rectangle-like estimate is performed in two or more sets of stereo images, the presumed error will decrease to 1/several statistics Kamigumi. Moreover, by performing average processing which carried out weighting for every part of each image based on it, if presumed error variance can be evaluated, the estimate is still more reliable and highly precise-ization is measured. Moreover, when correlation with the photographic subject configuration estimate of other groups makes are recording information adopted in a comprehensive operation only high photographic subject configuration estimate, the noise component on an image is removed effectively, the estimate is still more reliable and highly precise-ization is measured.

[0014] The high precision stereo vision system using the continuation frame image of this invention Two cameras which took predetermined spacing on

PRIOR ART

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[0003] Here, the principle of the geographical feature detection by the stereoscopic camera is explained. In the external world recognition by stereo ** using two cameras, the parallax of the point on an image is searched for from the corresponding points of the camera image of right and left by one photography, and the coordinate of the point is searched for based on a degree type.
x=b(xL+xR) /2dy=b(yL+yR)/— as f is parallax and shows a focal distance and b to drawing 3 for the base-line distance between cameras, and d 2 dz=bf/d here (xL, yL), (xR, yR) are the coordinates of the corresponding points in a right-and-left camera screen. Thus, if parallax is searched for by corresponding-points retrieval of each point on a camera image on either side and the distance to the point of the external world of from now on

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TECHNICAL FIELD

[Field of the Invention] the technique of recognizing geographical feature with a sufficient precision from two or more image information which photoed this invention with the stereoscopic camera which moves — being related — especially — the moon's surface — it is related with the technique of the stereoscopic camera suitable for the terrain sensing in the case of soft landing.

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EFFECT OF THE INVENTION

[Effect of the Invention] The high precision stereo vision using the continuation frame image of this invention The step which acquires two or more sets of stereo images from the view when the photographic subjects not deforming differ, The step which performs high corresponding-points retrieval of the correlation between the images of each class, and detects parallax, The step which calculates a photographic subject configuration from this parallax value, and the step which performs corresponding-points retrieval similarly, calculates a photographic subject configuration, and stores data between each class, Since it consists of a step which carries out the comprehensive operation of this are recording information, and makes photographic subject configuration estimate a clear thing, misconception of corresponding-points retrieval can be prevented and it becomes what has the high dependability of the parallax value as a stereo image. Moreover, since it is a thing synthesizing the photographic subject configuration estimate based on two or more sets of stereo images, the estimate is reliable and highly precise-ization is measured. As the comprehensive operation approach of are recording information, if average processing of radical rectangle-like estimate is performed in two or more sets of stereo images, the presumed error will decrease to 1/several statistics Kamigumi. Moreover, by performing average processing which carried out weighting for every part of each image based on it, if presumed error variance can be evaluated, the estimate is still more reliable and highly precise-ization is measured. Moreover, when correlation with the photographic subject configuration estimate of other groups makes are recording information adopted in a comprehensive operation only high photographic subject configuration estimate, the noise component on an image is removed effectively, the estimate is still more reliable and highly precise-ization is measured.
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corresponding is found, front geographical feature can be found.
[0004] Although there is some technique in corresponding-points retrieval of the camera image of the above right and left, area-based-matching is used for the typical thing. This evaluates the difference of the image for every pixel like for example, a degree type in the window set up on the camera image on either side as shown in drawing 4 .
[Equation 1]

$$J_1 = \sum_{i,j} | p_{ijL} - p_{ijR} | \quad : \text{絶対和}$$

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The performance index about the difference of the image in the window of such right and left is compared on a straight line, the points from which it becomes min are made into corresponding points, and distance information searched for from the parallax. However, when the similarity of the pattern in the location where it differs on the same image in that case is strong, or when there is an image noise, corresponding-points retrieval goes wrong, a different point is made to correspond, a parallax value is taken and calculated, and it happens to mistake presumption of geographical feature greatly. Moreover, as mentioned above, by the stereo image processing only using one frame of a camera, even if geographical feature detection of the whole screen can be impossible for it even if partial geographical feature detection is possible, or it can detect it, it may be accompanied by gross errors. Thus, this stereoscopic camera method is the difficulty of the corresponding-points retrieval between the images of two sheets etc., and a problem is in the certainty and implementation precision of geographical feature recognition.

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$$\underline{Z}_{ij}^{M} = \frac{1}{M}\sum_{k=1}^{M} Z_{ijk}$$

Then, it is good. Supposing distribution of the presumed error in each frame is given by sigmaij2, it is the presumed error variance of ZijM. sigmaij2 /M It turns out that it becomes and presumed error variance decreases to 1/M by processing of M frames. The information that dependability with few errors is high can be acquired by taking in data from two or more sets of images about the configuration (depth coordinate value) of each part of a photographic subject as mentioned above. In addition, it is [Equation 3] when taking serial processing into consideration.

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Then, saving of a storage region is [that what is necessary is to memorize only the presumed result of 1 time ago] possible.
[0009] (2) Estimate Zijk in the weighted-mean processing frame k The presumed error variance sigmaij2 If it can evaluate, the probability distribution of Zij which assumes the inter-frame independence of estimate and the normality of the presumed distribution of errors will be [Equation 4].

$$p_k(Z_{ij}) = \frac{1}{\sqrt{2\pi\sigma_{ijk}^2}}\exp\left\{-\frac{(Z_{ij}-\underline{Z}_{ijk})^2}{2\sigma_{ijk}^2}\right\}$$

The probability when obtaining the image of M frames, since it became is [Equation 5].

$$p(Z_{ij})_M = \left(\prod_k \frac{1}{\sqrt{2\pi\sigma_k^2}}\right)\times\exp\left\{-\sum_k\frac{(Z_{ij}-\underline{Z}_{ijk})^2}{2\sigma_{ijk}^2}\right\}$$

MEANS

[Means for Solving the Problem] The high precision stereo vision using the continuation frame image of this invention Acquire two or more sets of stereo images from the view when the photographic subjects not deforming differ, perform high corresponding-points retrieval of the correlation between the images of each class, and parallax is detected. While having calculated the photographic subject configuration from this parallax value, performing corresponding-points retrieval similarly in each class, calculating the photographic subject configuration and storing data, the comprehensive operation of these two or more sets of are recording information is carried out, and it was made to make photographic subject configuration estimate into the clear thing.
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[0008] Two or more stereo image information processing photoed continuously shows the technique of raising the increment in the count of observation with the recognition precision of geographical feature. First,

feature in absolute space, data cannot be synthesized, if coordinate transformation is carried out and it is not made in agreement. then, the moon's surface in which the camera was installed in this invention — an inertia sensor etc. detects the movement magnitude of a mobile like a probe, and it is made to carry out amendment conversion of each camera system of coordinates. Correspondence of two or more sets of frames which took a photograph on the time series target by this, and differed in system of coordinates, respectively is attained.

[0011] this invention — the moon's surface — the moon's surface of a probe — the moon's surface which is equivalent to the external world since the landing target geographical feature of using for the landing point observation in soft landing is eternal and the image of a continuation frame (it is several Hz with a present condition technique) can be acquired with landing descent — it is promising as a method of detecting geographical feature. however, this invention — the moon's surface — it is not restricted to the landing point observation in soft landing, in addition can apply to the external world recognition technique in autonomous mobiles, such as a robot, as it is. Moreover, since it is a thing synthesizing the image from a different view, this invention goes into an objective shadow etc., can acquire the image of the part from a different view also about the field (occlusion) where corresponding points do not exist by the camera image on either side, and enables recognition of the shape of surface type without an omission.

[0012]

[Example 1] The basic block diagram of the example of a system in which this invention can be carried out is shown in drawing 1 , and the flow chart of drawing 2 explains the actuation. First, predetermined spacing is given as equipment and the left-hand side camera L and the right-hand side camera R are directly fixed to an airframe. The photography image of a camera on either side is serially accumulated in the image memory area of each RAM using the camera which these cameras L and R are equipped with image sensors, such as CCD, and outputs digital information. [Step 1] This system is equipped with a computer, and CPU of this computer performs corresponding-points retrieval which carries out the comparison (difference) operation for every pixel of both images, and becomes high [a correlation] most about all pixels, and calculates the boom-hoisting information on geographical feature based on [step 2] and this parallax value in quest of parallax [step 3]. After taking in data about two or more sets of stereo images, performing coordinate transformation based on the movement magnitude of the airframe separately measured by the inertia sensor etc. about the boom-hoisting information which asked by performing the same operation and changing into the boom-hoisting information in a certain standard coordinates, sequential storage are recording is carried out. [Step

It becomes. The optimum estimate (maximum likelihood estimation) when obtaining the image of M frames, when writing what changed the sign of exponent part to be J is [Equation 6].

$$\frac{\partial J}{\partial Z_{ij}} = \sum_k \frac{(Z_{ij} - Z_{ijk})}{\sigma^2_{ijk}} = 0$$

It is [Equation 7] more.

$$\underline{Z}^M_{ij} = \left(\sum_k \frac{1}{\sigma^2_{ijk}}\right)^{-1} \left(\sum_k \frac{Z_{ijk}}{\sigma^2_{ijk}}\right)$$

** — the addition with weight of the presumed error in each frame [like] — then, it is good. Namely, presumed error variance sigmaij2 of each frame By based weighting, information more reliable than mere averaging can be acquired about the configuration (depth coordinate value) of each part of a photographic subject. In addition, the formula deformation to a serial-processing mold is [Equation 8] like the case of previous averaging.

$$\frac{1}{\underline{\sigma}^2_{ijM}} = \sum_{k=1}^{M} \frac{1}{\sigma^2_{ijk}}$$

とすれば

$$\frac{1}{\underline{\sigma}^2_{ijM}} = \frac{1}{\sigma^2_{ijM}} + \frac{1}{\underline{\sigma}^2_{ij(M-1)}}$$

$\underline{Z}^M_{ij}$ は上記を使って

$$\underline{Z}^M_{ij} = \underline{\sigma}^2_{ijM} \left(\frac{Z_{ijM}}{\sigma^2_{ijM}} + \underline{\sigma}^2_{ij(M-1)} \underline{Z}^{M-1}_{ij} \right)$$

と逐次的に求まる。

An operation can be performed as mentioned above with the count using the presumed result of 1 time ago, then small storage capacity.

[0010] now, the moon's surface — although the image serially photoed with the camera installed on a mobile like a probe is in agreement in a camera coordinate, the camera coordinate at each photography time differs in the physical relationship over a photographic subject. If it is the geographical feature of the photographic subject configuration which should be searched for, for example, the moon's surface, it is required the coordinate on the basis of the moon's surface and to ask as information [in / generally / a absolute space coordinate]. Since the camera coordinate corresponding to each frame is different from two or more sets of frames photoed serially [while the camera is exercising] in order to search for the geographical

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is drawing showing the basic configuration of the high precision stereo vision system using the continuation frame image of this invention.
[Drawing 2] It is a flow chart explaining actuation of this invention.
[Drawing 3] It is drawing explaining the principle of a stereo vision.
[Drawing 4] It is drawing explaining the corresponding points of the image of the right and left in a stereo vision.
[Description of Notations]
b Distance between cameras P Pixel image
X, Y, Z Absolute-coordinate shaft OL Left camera optical axis
XL, YL Left camera axis of coordinates OR Right camera optical axis
XR, YR Right camera axis of coordinates

[Translation done.]

4] This computer is equipped with the function which carries out comparison examination of the boom-hoisting information on the geographical feature computed from two or more sets of stereo images again [step 6]. That is, when a difference with the data of others [data / of a certain group / configuration presumption] is large, based on majority rule, the stereo image is judged to be what has taken corresponding-points retrieval, and redoes corresponding-points retrieval. In that case, processing which carries out the comparison with the image data of other groups since the noise can be contained in the image, and makes the data of a bad mutually related part a rejection is performed. That is, the image data of the part where estimate differs greatly is deleted [step 8]. Retrieval of corresponding points is again performed based on clear image data, and parallax is deduced [step 9]. Based on a new parallax value, the configuration estimate of the group is calculated again and overwrite storage is carried out [step 10]. The terrain intelligence which performed average processing or average processing with weight for the data adopted as two or more sets of stereo images being effective, and raised dependability is calculated [step 11]. The configuration optimal-estimation information on the calculated result is memorized, and [step 12] and an activity are ended. in addition, this system -- the moon's surface -- if it is in a probe, communication link connection is made with the controller of its remote command post like a terrestrial pin center,large, and the display for monitors.

[Translation done.]

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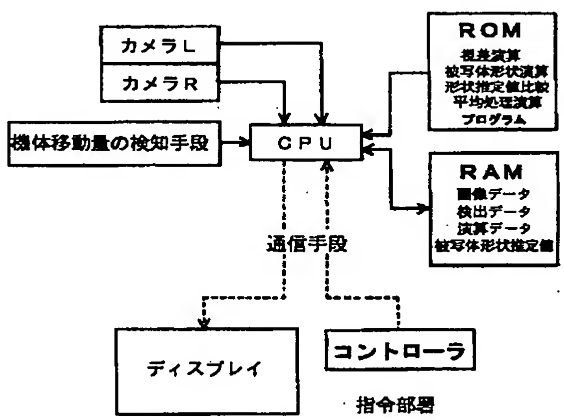
最終頁に続く

(54)【発明の名称】 連続フレーム画像を用いた高精度ステレオビジョン

(57)【要約】
【課題】 本発明の課題は、上記のようなステレオカメラ方式における問題点を解決し、二枚の画像間の対応点探索を確かなものとすることで視差の値の割りだしを正確にし、よって被写体形状認識の確実性を増すと共に、その再現精度が高いステレオカメラ方式を提供することにある。
【解決手段】 本発明の連続フレーム画像を用いた高精度ステレオビジョンは、変形しない被写体の異なる視点からのステレオ画像を複数組取得して各組の画像間の相関関係の高い対応点探索を実行して視差を検知し、該視差値から被写体形状を演算し、各組間においても同様に対応点探索を実行して被写体形状を演算してデータを蓄積すると共に該蓄積情報を総合演算して被写体形状推定値を確かなものとするようにした。



【特許請求の範囲】

【請求項１】　変形しない被写体の異なる視点からのステレオ画像を複数組取得するステップと、各組の画像間の相関関係の高い対応点探索を実行して視差を検知するステップと、該視差値から被写体形状を演算するステップと、各組においても同様に対応点探索を実行して被写体形状を演算してデータを蓄積するステップと、複数組の該蓄積情報を総合演算して被写体形状推定値を確かなものとするステップとからなる連続フレーム画像を用いた高精度ステレオビジョン。

【請求項２】　蓄積情報の総合演算方法は、複数組のステレオ画像に基く形状推定値の平均処理又は重み付き平均処理である請求項１に記載の連続フレーム画像を用いた高精度ステレオビジョン。

【請求項３】　他の組の被写体形状推定値との相関が低い被写体形状推定値は総合演算において採用される蓄積情報から除外されるようにした請求項１又は２に記載の連続フレーム画像を用いた高精度ステレオビジョン。

【請求項４】　移動できる物体に所定間隔をとって据えつけられた２台のカメラと、該２台のカメラによって撮影された画像を記憶する記憶手段と、該記憶された２枚の画像から対応点探索を実行して視差を割り出す手段と、前記視差値から被写体形状を推定演算する手段と、視角を異にする複数組のステレオ画像に基く被写体形状情報を総合演算して被写体形状推定値を確かなものとする手段とからなる連続フレーム画像を用いた高精度ステレオビジョンシステム。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、移動するステレオカメラで撮影した複数の画像情報から地形を精度よく認識する技術に関し、特に月面軟着陸の際の地形判定に適したステレオカメラの技術に関する。

【０００２】

【従来の技術】所定距離離れて設置された二台のカメラで撮影した二枚の画像をもとに、被写体の三次元形状を認識するステレオ写真の技術は、左右の目で二枚の画像を別々に見て視覚によって立体視させるものや、二枚の画像中から対応する点情報を見つけその視差からその点の奥行き座標を演算で求める技術が知られている。ところで、わが国において近い将来無人の月面探査機を月面に軟着陸させる計画があり、その月面軟着陸を確実にするには、月面に分布するクレータや岩石などの位置を認識し、それを回避すべく探査機を誘導・制御する技術が重要となる。そのためには視界情報を用いた地形の認識が必須で、このステレオカメラを用いた三次元形状認識技術、前述の後者の方式が注目されている。

【０００３】ここで、ステレオカメラによる地形検出の原理を説明する。２台のカメラを用いたステレオ視による外界認識においては、１回の撮影による左右のカメラ画像の対応点から画像上の点の視差を求め、次式に基づきその点の座標を求める。

$$x = b(x_L + x_R)/2d$$

$$y = b(y_L + y_R)/2d$$

$$z = bf/d$$

ここでｆは焦点距離、ｂはカメラ間のベースライン距離、ｄは視差であり、図３に示すように（x_L，y_L），（x_R，y_R）は左右カメラ画面での対応点の座標である。このように左右のカメラ画像上の各点の対応点探索により視差を求め、これから対応する外界の点までの距離を求めれば、前方の地形が求まることになる。

【０００４】上記のような左右のカメラ画像の対応点探索にはいくつかの手法があるが、その代表的なものは、ａｒｅａ・ｂａｓｅｄ・ｍａｔｃｈｉｎｇを用いるものである。これは図４に示すように左右のカメラ画像上に設定したウインドー内において各ピクセルごとの画像の差を、例えば次式のように評価する。

【数１】

$$J_1 = \sum_{i,j} |p_{ijL} - p_{ijR}| \quad : \text{絶対和}$$

$$J_2 = \sum_{i,j} (p_{ijL} - p_{ijR})^2 \quad : \text{誤差二乗和}$$

このような左右のウインドー内の画像の差に関する評価関数を直線上で比較し、それが最小になる点どうしを対応点とし、その視差から距離情報を求めるものである。ところがその場合、同一画像上の異なる場所でのパターンの類似性が強い場合や、画像ノイズがある場合には対応点探索に失敗し、異なる点を対応させてしまい視差値を誤認して計算し、地形の推定を大きく誤ることが起こる。また、以上のようにカメラの１フレームのみを用いたステレオ画像処理では、部分的な地形検出は可能であっても画面全体の地形検出が不可能であったり、検出できても大きな誤差を伴う場合もある。このようにこのステレオカメラ方式は、二枚の画像間の対応点探索の難しさなどで、地形認識の確実性や実現精度に問題がある。

【０００５】

【発明が解決しようとする課題】本発明の課題は、上記のようなステレオカメラ方式における問題点を解決し、二枚の画像間の対応点探索を確かなものとすることで視差の値の割りだしを正確にし、よって被写体形状認識の確実性を増すと共に、その再現精度が高いステレオカメラ方式を提供することにある。

【０００６】

【課題を解決するための手段】本発明の連続フレーム画像を用いた高精度ステレオビジョンは、変形しない被写体の異なる視点からのステレオ画像を複数組取得して各組の画像間の相関関係の高い対応点探索を実行して視差を検知し、該視差値から被写体形状を演算し、各組においても同様に対応点探索を実行して被写体形状を演算してデータを蓄積すると共に複数組の該蓄積情報を総合演

算して被写体形状推定値を確かなものとするようにした。

【０００７】

【発明の実施の形態】本発明は、被写体形状が不変であり、カメラが移動体につけられたりして異なる視点からの連続した画像が取得できる場合には、各フレームで得られた形状情報を蓄積して、総合判断すれば画像間の対応点探索において対応点を誤認する確率は減少し、各地点毎の情報も信頼性が高くなるという基本思想に基くものである。すなわち、異なる角度､異なる視野からの画像を基にしてある部分の特定を実行すれば、個々の点については画像上のランダムノイズの影響は平均化されることで少なくなる。その結果月面地形の観測においては検出領域を拡張したり、地形推定の高精度化をはかることが可能である。

【０００８】連続して撮影された複数のステレオ画像情報処理により、地形の認識精度を観測回数の増加に伴い向上させる手法について示す。まず、高精度化のための統計処理についてであるが、本発明では①平均処理と②重み付き平均処理の手法を採用した。

（１）平均処理

対象（被写体）表面を絶対空間座標（Ｘ，Ｙ，Ｚ）で表すものとし、その二次元座標上の格子点（X_i，Y_j）における地形（奥行き座標値）$Z_{i,j}$のフレーム画像ｋにおける推定値を$\underline{Z}_{ijk}$で表すものとする。このとき連続したステレオカメラ撮影でＭ個の推定値が得られたら、Ｍ番目までのフレーム情報を用いた地形の推定値は、それらの平均値により

【数２】

$$\underline{Z}_{ij}^{M}=\frac{1}{M}\sum_{k=1}^{M}\underline{Z}_{ijk}$$

とすればよい。各フレームにおける推定誤差の分散がσ_{ij}^2で与えられるとすると、$\underline{Z}_{ij}^{M}$の推定誤差分散は　σ_{ij}^2　／Ｍ　となり、推定誤差分散がＭ個のフレームの処理により、１／Ｍに減少することが分かる。以上のように被写体の各部分の形状（奥行き座標値）に関し、複数組の画像からデータを取りこむことにより誤差の少ない信頼性の高い情報を得ることができる。なお逐次処理を考慮する場合は

【数３】

$$\underline{Z}_{ij}^{M}=\frac{1}{M}\left\{\underline{Z}_{ijM}+(M-1)\underline{Z}_{ij}^{M-1}\right\}$$

とすれば、１回前の推定結果のみを記憶するだけでよく、記憶領域の節約が可能である。

【０００９】（２）重み付き平均処理

フレームｋにおける推定値$\underline{Z}_{ijk}$　と、その推定誤差分散σ_{ij}^2　が評価可能であるなら、推定値のフレー

ム間の独立性や推定誤差分布の正規性を仮定するZ_{ij}の確率分布は

【数４】

$$p_k(Z_{ij})=\frac{1}{\sqrt{2\pi\sigma_{ijk}^2}}\exp\left\{-\frac{(Z_{ij}-\underline{Z}_{ijk})^2}{2\sigma_{ijk}^2}\right\}$$

となるので、Ｍ個のフレームの画像を得た時の確率は

【数５】

$$p(Z_{ij})_M=\left(\prod_k\frac{1}{\sqrt{2\pi\sigma_k^2}}\right)\times\exp\left\{-\sum_k\frac{(Z_{ij}-\underline{Z}_{ijk})^2}{2\sigma_{ijk}^2}\right\}$$

となる。指数部の符号を変えたものをＪと書けば、Ｍ個のフレームの画像を得た時の最適推定値（最尤推定）は

【数６】

$$\frac{\partial J}{\partial Z_{ij}}=\sum_k\frac{(Z_{ij}-\underline{Z}_{ijk})}{\sigma_{ijk}^2}=0$$

より

【数７】

$$\underline{Z}_{ij}^{M}=\left(\sum_k\frac{1}{\sigma_{ijk}^2}\right)^{-1}\left(\sum_k\frac{\underline{Z}_{ijk}}{\sigma_{ijk}^2}\right)$$

のような、各フレームにおける推定誤差の重み付き加算とすればよい。すなわち、各フレームの推定誤差分散σ_{ij}^2　に基く重み付けにより、被写体の各部分の形状（奥行き座標値）に関し単なる加算平均よりも信頼性の高い情報を得ることが出来る。なお、逐次処理型への式変形は先の加算平均の場合と同様に

【数８】

$$\frac{1}{\sigma_{ijM}^2}=\sum_{k=1}^{M}\frac{1}{\sigma_{ijk}^2}$$

とすれば

$$\frac{1}{\sigma_{ijM}^2}=\frac{1}{\sigma_{ijM}^2}+\frac{1}{\sigma_{ij(M-1)}^2}$$

$\underline{Z}_{ij}^{M}$　は上記を使って

$$\underline{Z}_{ij}^{M}=\sigma_{ijM}^2\left[\frac{\underline{Z}_{ijM}}{\sigma_{ijM}^2}+\sigma_{ij(M-1)}^2\,\underline{Z}_{ij}^{M-1}\right]$$

と逐次的に求まる。

上記のように一回前の推定結果を用いる計算とすれば、少ない記憶容量で演算が実行できる。

【００１０】さて、月面探査機のような移動体上に設置されたカメラで時系列的に撮影された画像はカメラ座標において一致しているものの、各撮影時点のカメラ座標は被写体に対する位置関係を異にしている。求めるべき

被写体形状、例えば月面の地形であれば月面を基準とした座標、一般的には絶対空間座標における情報として求めることが必要である。カメラが運動しているときに時系列的に撮影した複数組のフレームから、絶対空間での地形を求めるためには、各フレームに対応するカメラ座標が相違しているので、座標変換し一致させなければデータを綜合することができない。そこで、本発明ではカメラを設置した月面探査機のような移動体の移動量を慣性センサ等により検出し、各カメラ座標系を補正変換するようにしている。これにより時系列的に撮影しそれぞれ座標系を異にした複数組のフレームの対応が可能となる。

【００１１】本発明を月面探査機の月面軟着陸における着地点観測に用いることは、着地目標地形は不変であり、着陸降下に伴い連続フレーム（現状技術で数Ｈｚ）の画像が取得できるため、外界に相当する月面地形の検出法として有望である。しかし本発明は月面軟着陸における着地点観測に限られず、この他、ロボットなど自律移動体における外界認識技術にそのまま応用することができる。また、本発明は異なる視点からの画像を綜合するものであるため、物体の影などに入り、左右のカメラ画像で対応点の存在しない領域（オクルージョン）についても、異なる視点からその部分の画像を取得することができ、抜けのない表面形状の認識を可能にするものである。

【００１２】

【実施例１】本発明を実施できるシステムの具体例の基本構成図を図１に示し、その動作を図２のフローチャートによって説明する。まず、装置として所定間隔をもたせて左側のカメラＬと右側のカメラＲを機体に直接固定する。該カメラＬ，ＲはＣＣＤ等の撮像素子を備えデジタル情報を出力するカメラを用い、左右のカメラの撮影画像は逐次それぞれのＲＡＭの画像メモリ領域に蓄積される。［ステップ１］このシステムはコンピュータを備え、該コンピュータのＣＰＵは両画像の画素毎の比較（差）演算をして全画素について最も相関関係の高くなる対応点探索を実行して視差を求め［ステップ２］、この視差値に基いて地形の起伏情報を演算する［ステップ３］。複数組のステレオ画像についてデータを取りこみ同様の演算を行って、求めた起伏情報について慣性センサなどにより別途計測された機体の移動量に基く座標変換を施しある基準座標系における起伏情報に変換した後、順次記憶蓄積する。［ステップ４］また、このコンピュータは複数組のステレオ画像から算出した地形の起伏情報を比較検討する機能を備えている［ステップ６］。すなわち、ある組の形状推定データが他のデータとの差が大きいときは、多数決原理に基きそのステレオ画像は対応点探索を誤認しているものと判断し、対応点探索をやり直す。その場合、画像にノイズが入っていることがあり得るので他の組の画像データとの比較をし、相関の悪い部分のデータを不採用とする処理を行う。すなわち、推定値が大きく異なる個所の画像データを削除する［ステップ８］。確かな画像データをもとに再度対応点の探索を実行し視差を割り出す［ステップ９］。新たな視差値をもとに再度その組の形状推定値を演算し、上書き記憶する［ステップ10］。複数組のステレオ画像の有効として採用されたデータを平均処理、或いは重み付きの平均処理を実行して信頼性を高めた地形情報を演算する［ステップ11］。演算した結果の形状最適推定情報を記憶し［ステップ12］、作業を終了する。なお、このシステムは月面探査機にあっては地上のセンターのような遠隔の指令部署のコントローラやモニター用のディスプレイと通信接続されている。

【００１３】

【発明の効果】本発明の連続フレーム画像を用いた高精度ステレオビジョンは、変形しない被写体の異なる視点からのステレオ画像を複数組取得するステップと、各組の画像間の相関関係の高い対応点探索を実行して視差を検知するステップと、該視差値から被写体形状を演算するステップと、各組間においても同様に対応点探索を実行して被写体形状を演算してデータを蓄積するステップと、該蓄積情報を総合演算して被写体形状推定値を確かなものとするステップとからなるものであるから、対応点探索の誤認が防止でき、ステレオ画像としての視差値の信頼性が高いものとなる。また、複数組のステレオ画像をもとにした被写体形状推定値を綜合するものであるため、その推定値は信頼性が高く、高精度化が計られたものである。蓄積情報の総合演算方法として、複数組のステレオ画像に基く形状推定値の平均処理を行えば、その推定誤差は統計上組数分の１に減少することになる。又、推定誤差分散が評価可能であるならば、それに基いて各画像の部分毎に重み付けをした平均処理を行うことで、更にその推定値は信頼性が高く、高精度化が計られる。また、総合演算において採用する蓄積情報を、他の組の被写体形状推定値との相関が高い被写体形状推定値のみとすることにより、画像上のノイズ成分を効果的に除去して更にその推定値は信頼性が高く、高精度化が計られる。

【００１４】本発明の連続フレーム画像を用いた高精度ステレオビジョンシステムは、移動できる物体に所定間隔をとって据えつけられた２台のカメラと、該２台のカメラによって撮影された画像を記憶する記憶手段と、該記憶された２枚の画像から対応点探索を実行して視差を割り出す手段と、前記視差値から被写体形状を演算する手段と、視角を異にする複数組のステレオ画像に基く被写体形状を総合演算して被写体形状推定値を確かなものとする手段とからなるものであって、ハードとしてはカメラとコンピュータと距離検出手段を備えていればよく、このシステムは月面探査機やロボットなどに搭載が可能である。そして、この構成によって上記したような

高精度ステレオビジョンとしての効果を奏するものであるから、月面軟着陸における目的地形の推定や自律移動における外界認識のシステムとして大いに有望である。

【図面の簡単な説明】

【図１】本発明の連続フレーム画像を用いた高精度ステレオビジョンシステムの基本構成を示す図である。

【図２】本発明の動作を説明するフローチャートである。

【図３】ステレオビジョンの原理を説明する図である。＊

＊【図４】ステレオビジョンにおける左右の画像の対応点を説明する図である。

【符号の説明】

b　カメラ間距離

X，Y，Z　絶対座標軸

X_L，Y_L　左カメラ座標軸

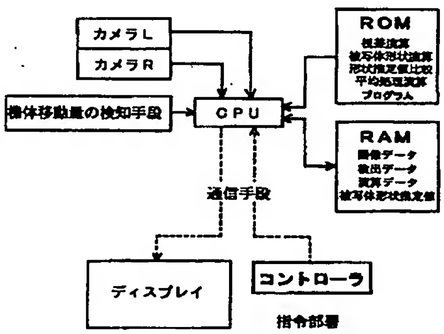
X_R，Y_R　右カメラ座標軸

P　ピクセル画像

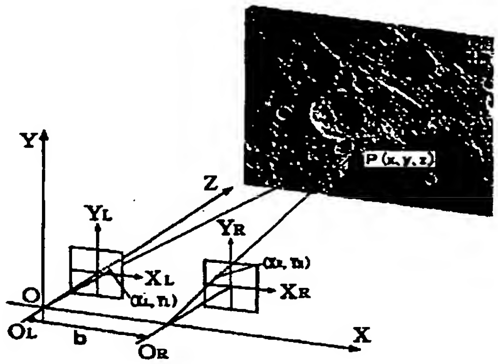
O_L　左カメラ光学軸

O_R　右カメラ光学軸

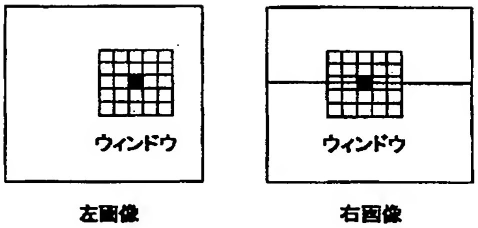
【図１】



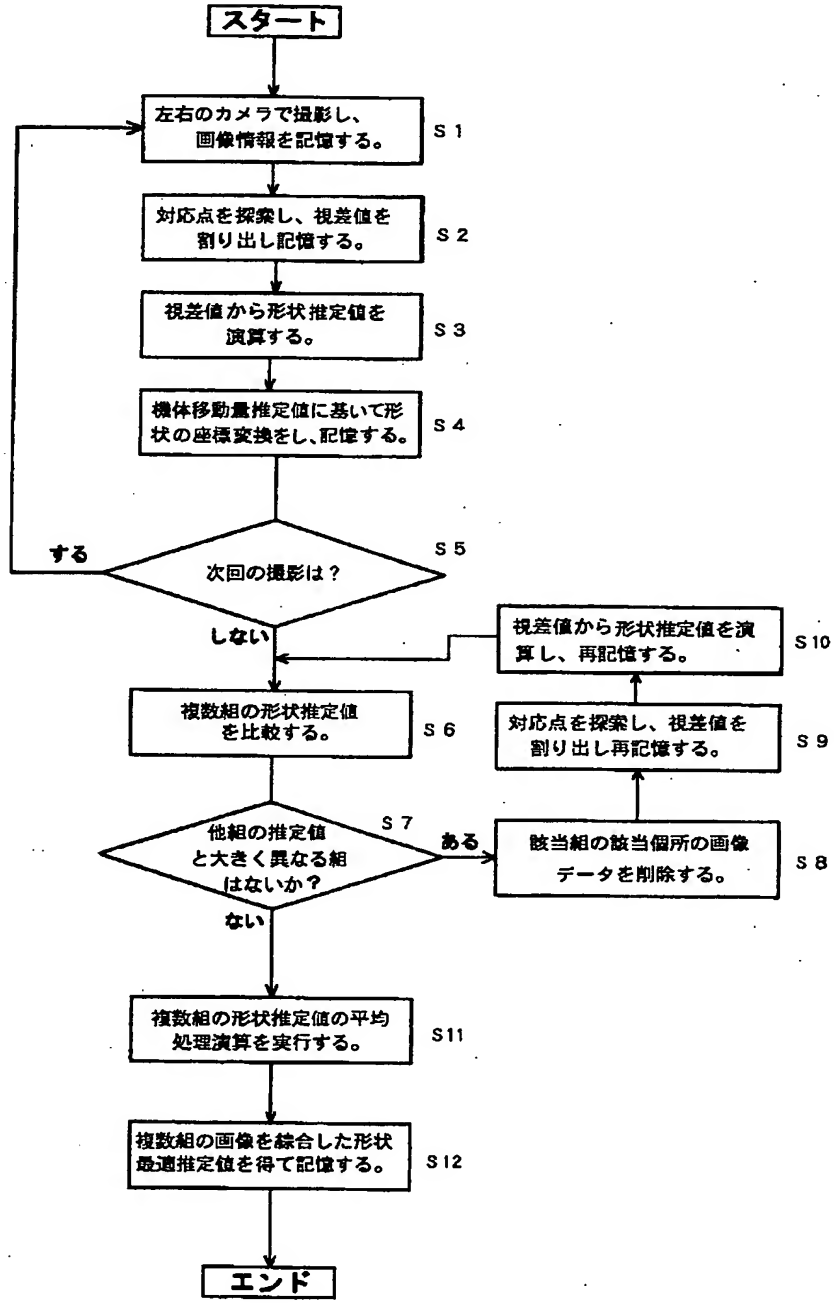
【図３】



【図４】



【図２】


スタート
左右のカメラで撮影し、画像情報を記憶する。
S1
対応点を探索し、視差値を割り出し記憶する。
S2
視差値から形状推定値を演算する。
S3
機体移動量推定値に基いて形状の座標変換をし、記憶する。
S4
次回の撮影は？
S5
する
しない
複数組の形状推定値を比較する。
S6
他組の推定値と大きく異なる組はないか？
S7
ある
ない
該当組の該当個所の画像データを削除する。
S8
対応点を探索し、視差値を割り出し再記憶する。
S9
視差値から形状推定値を演算し、再記憶する。
S10
複数組の形状推定値の平均処理演算を実行する。
S11
複数組の画像を総合した形状最適推定値を得て記憶する。
S12
エンド

フロントページの続き

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